Simple process to fabricate nitride alloy powders

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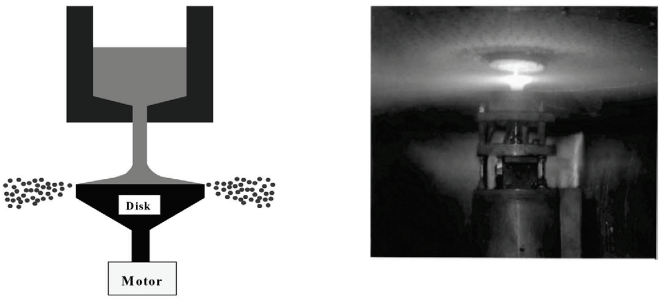
Introduction

Uranium mono-nitride (UN) is considered as a fuel material [1] for accident-tolerant fuel to compensate for the loss of fissile fuel material caused by adopting a thickened cladding such as SiC composites.

Uranium nitride powders can be fabricated by a carbothermic reduction [2] of the oxide powders, or the nitriding of metal uranium [3]. Among them, a direct nitriding process of metal is more attractive because it has advantages in the mass production of high-purity powders and the reusing of expensive $^{15}N_2$ gas. However, since metal uranium is usually fabricated in the form of bulk ingots, it has a drawback in the fabrication of fine powders.

Figure 1: (a) Schematics of atomisation process, (b) Video capture image



(a) (b)

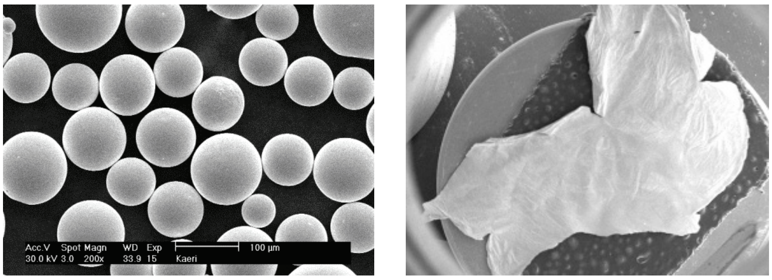
The Korea Atomic Energy Research Institute (KAERI) has a centrifugal atomisation technique to fabricate uranium and uranium alloy powders. In this study, a simple reaction method was tested to fabricate nitride fuel powders directly from uranium metal alloy powders. Spherical powder and flake of uranium metal alloys were fabricated using a centrifugal atomisation method. The nitride powders were obtained by thermal treating the metal particles under nitrogen containing gas. The phase and morphology evolutions of powders were investigated during the nitriding process. A phase analysis of nitride powders was also part of the present work.

Centrifugal atomising process

KAERI has developed the centrifugal rotating disk atomisation process to fabricate spherical uranium metal alloy powders which are used as advanced fuel materials for research reactors [4].

As shown in Figure 1, the rotating disk atomisation system involves the tasks of melting, atomising, and collecting. A nozzle in the bottom of melting crucible introduces melt at the center of a spinning disk. The centrifugal force carries the melt to the edge of the disk and throws the melt off the edge. Size and shape of droplets can be controlled by changing the nozzle size, the disk diameter and disk speed independently or simultaneously. By adjusting the processing parameters of the centrifugal atomiser, a spherical and flake shape alloy powders were obtained. Figure 2 shows the typical morphologies of the obtained particles.

Figure 2: Typical powder morphologies, (a) Spherical U-10 wt% Zr powder (b) U flake



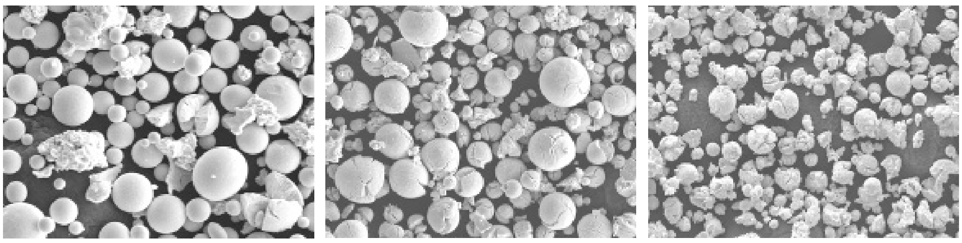
(a) (b)

Nitride powders fabrication

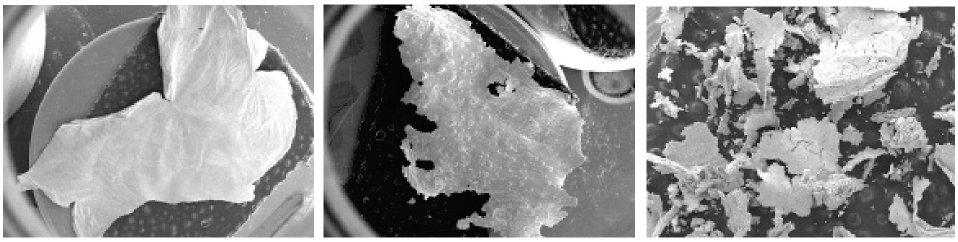
Two types of the simple thermal treatment procedures were tested to fabricate nitride powders.

First, the procedure is a direct nitriding process in which the metal powders were annealed at 1 000^{0}C under nitrogen gas and then further annealed at 1 500^{0}C under hydrogen containing Ar gas atmosphere. Figure 3 shows the shape evolution of U metal particles during the successive annealing step. It was revealed that the particles were fragmented to smaller particles during the annealing. The XRD results showed that the uranium metal converted to UN_2 phase during the annealing at 1 000^{0}C and then decomposed to UN phase during the further annealing at 1 500^{0}C.

Figure 3: Powder morphology evolution during the direct nitriding process (a) U spherical powder (b) U flake



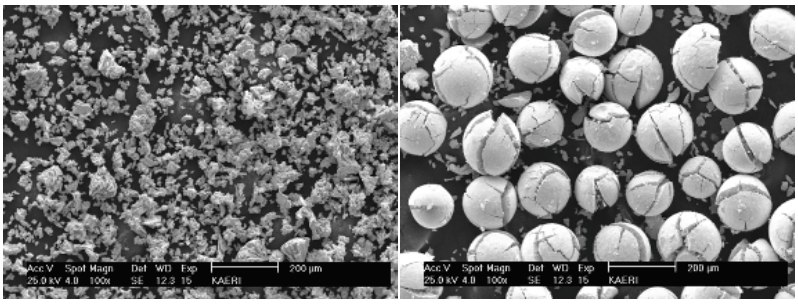
(a)



(b)

Observed fragmentation and cracking of particles were caused by sequential volume changes of expansion and contraction which were accompanied by the formation and decomposition of uranium nitrides. Although uranium nitride powders were successfully fabricated during the simple nitriding process, it seems that milling of the obtained powder might be necessary to fabricate sintered nitride fuel pellets.

Figure 4: Powder morphology evolution after the modified nitriding process (a) U metal, (b) U-10 wt% Zr



(a) (b)

In order to fabricate finer nitride powders, a nitriding procedure has been modified. In the modified process, the particles were heat-treated at 250°C in H_2 before nitriding. Figure 4 shows the nitride powders obtained by the modified process. The addition of a hydriding step [5] was effective in obtaining fine uranium nitride powder as shown in Figure 4(a). In the case of U-10 wt% Zr-alloy, however, only a few large cracks were developed on the particle surface and the particle maintained its size as shown in Figure 4(b). This result reveals that hydriding and nitriding kinetics or mechanisms of U-10 wt% Zr alloy are quite different from those of U metal.

Summary

Nitriding the U metal and alloy particles obtained through centrifugal atomisation is a simple and effective method to fabricate the nitride fuel powders.

References

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